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TTY Over Cellular and PCS
Laboratory and Field Test Procedure

FDMA/TDMA/CDMA

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Abstract: The purpose of this document is to establish an objective test for measuring the performance of TTYs over Cellular and PCS Networks.

DOCUMENT REVISION HISTORY

VERSION	DESCRIPTION	DATE	CREATED/UPDATED BY
1.0	Initial Document	9-02-98	Steve Mead, Pete Cabral, Billy Ragsdale Joshua Lober
1.1	Modified per TTY Forum input	9-13-98	Joshua Lober per TTY Forum
1.1 comments from iDEN	Added comments from iDEN Group	10-29-98	Mario Remon/Audrey Longhurst per iDEN Subscriber Division

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TTY OVER CELLULAR TEST PROCEDURE

1. OVERVIEW

1.5 INTRODUCTION

This procedure defines a configuration in which a TTY device can be objectively tested over any cellular or PCS network. This procedure shall be followed regardless of the cellular format. Therefore, this test format shall work for FDMA Analog Cellular Networks (AMPS), as well as TDMA and CDMA Digital Cellular/PCS Networks (IS-136, GSM, CDMA, and iDEN). The comments added to this document are applicable for iDEN, Not all comments will be applicable for other technologies.

In a field test, there are uncontrolled elements which cause a greater variation in test results. A portion of the tests in this procedure will first be executed using a simple laboratory configuration, so that all these test conditions will be repeatable over multiple tests. After results have been achieved through documented simple laboratory configurations, the test will be repeated in a real world environment (field testing).. During this stage, it is very important that all manufactures of digital wireless phones/technologies and TTY manufactures participate, as results of this simple laboratory test stage will be used in the field test stage.

Once results are reached that are equal to or better than analog, the second stage of laboratory testing can begin. The second stage (not specified in this document) shall include the wire-line 9-1-1 network with the calls going to a Public Safety Access Point (PSAP) with the existing TTY equipment in use today. The test scripts used in the second stage of testing shall be designed for real life applications, determining that configurations submitted actually do perform equal to or better than analog. These test scripts shall be designed by subject matter experts (SMEs) in TTY call processing to 9-1-1 PSAPs. These test scripts shall first be executed over an analog wireless network, and then with a digital network to compare the final results in determination of equality. These test scripts should consider use of VCO/HCO

1.6 SCOPE

It is not the intention of this document to define acceptance criteria, but rather provide an even playing field where all devices and cellular formats can be evaluated. The evaluation and interpretation of the data are not addressed. Test results shall be recorded in terms of Printed Character Error Rates (PCER), and Total Character Rates (TCER). Because various cellular formats as well as various TTY devices will be tested, wherever possible attempts shall be made to reduce variables in the test scenarios.

1.7 DESCRIPTION OF TEST STRATEGY

1.7.1 Baseline Measurements for Digital Technologies

Due to the difficulty in determining acceptable performance criteria of script transmission over a Digital Cellular Channel, it is it is required that a baseline first be determined. Currently, Analog cellular has been accepted by the general public for TTY communication, and should therefore be used as a baseline for digital testing. Each test called out in this procedure shall first be base-lined with an analog test, the results to be compared to the digital tests. Therefore, if a car driving 65MPH is not capable of scoring a low Character Error Rate using analog technology, it is not reasonable to expect better low Character Error Rates from a digital technology.

1.7.2 Stage 1 Test Script

Much attention has been placed on the test script and it's evaluation method. Due to earlier discussion, a script of randomly generated characters alternating between letters and figures has been generated. The code used to generate the test script is located in Appendix A, and the script itself in located in Appendix B. The test script contains 4216 characters, and the number of shift characters generated by the TTY will be 2012. There is a maximum of eight consecutive letters or figures, and a maximum total of 6228 characters will be scored. The scoring guidelines have been modified as they apply to shift errors, please see section 0 for details.

1.7.3 Additional Stop BITS (optional)

It was determined in the earlier testing that improved CER performance could be achieved by adding additional stop BITS to BAUDOT characters transmitted over a TDMA traffic channel. In TTY devices, there is no formal specification for the quantity of stop bits, only a recommended minimum of 1.5. Therefore, each TTY manufacturer may vary the quantity of stop bits as they see fit. If additional stop BITS are to be used during these tests, they may only be used in the direction from the mobile TTY to land TTY. In addition, a maximum of three additional stop bits (five stop BITS total) may used for each character. This delay will reduce the Word per Minute (WPM) rate from 68.18 WPM to 49.58 WPM (based on five character words and two stop bits).

Additional Stop BITS	Bit Rate	Add'l Stop BIT Time	Word Rate	WPM
0	2.20E-02	0.00E+00	8.80E-01	68.18
1	2.20E-02	2.20E-02	9.90E-01	60.60
2	2.20E-02	4.40E-02	1.10E+00	54.54
3	2.20E-02	6.60E-02	1.21E+00	49.58

1.7.4 Signal Strengths

For these tests, three signal strengths have been selected. Each technology group shall define and submit appropriate levels to be used for these tests. These levels may be in terms of RSSI, BER, FER or any terms appropriate for that technology. The levels listed below are to be used for the AMPS baseline testing, and should be used as a guideline for the digital technology groups in their definitions.

1.7.4.1 Strong Signal

The strong signal test is representative of communication within close proximity to a base station. A power level of –55dBm +/- 3dB has been selected as the Received Signal Strength Indication (RSSI) as measured by the mobile unit or other measurement equipment in place. [removed since this does not apply to TDMA based systems such as iDEN]

1.7.4.2 Moderate Signal

A power level of –75dBm +/-5dB has been selected as the Received Signal Strength as measured by the mobile unit or other measurement equipment in place. This number was chosen as it represents typical minimum RSSI found in urban environments, and is the midpoint to the strong and weak signal levels selected.

1.7.4.3 Weak Signal

A power level of –95dBm +/-5dB has been selected as the Received Signal Strength as measured by the mobile unit or other measurement equipment in place. This level has been chosen because a base station located in a rural service area typically broadcasts it's control channel at 17 Watts, and voice channels at 20 Watts. A hand-held mobile with a Power Class Mark of III transmits at 0.63 Watts, approximately 15dB lower than the base station. Therefore, the base station will receive this mobile from –110dBm +/- 5dB. Per IS-20 Performance Specifications, AMPS base stations

are required to have a 12dB SINAD at –116dBm. This level is considered to be the minimum operating condition for an AMPS system.

1.7.5 Test Equipment Configuration

At this time there is no standardized interface between TTY devices and Cellular/PCS Phones. There are variations in interface connectors and voltages. It is required that the phone and TTY be "matched" before reliable testing can proceed (see section 3.1). It is also required that each manufacturer provide instructions for the call origination and termination on a case by case basis. These instructions may be part of the Users Manual, or they may be special documents. Attached in the appendices of this document are examples of such documents, describing interoperability between the CPT Mobility™ TTY and various Cellular Phones.

2. TEST ENVIRONMENT

2.5 HARDWARE REQUIREMENTS

Hardware required for this test include:

- TTY device to be tested over Cellular or PCS Network.
  (TTY must be capable of outputting received characters to a parallel or serial port, and sending random character script.)
- Cellular or PCS Phone.
- Ultratec InteleModem
- Cellular Product Technologies Mobility™ TTY
- Two Personal Computers (i386 or better) with:
  4 MB of RAM (minimum)
  3.5 MB (minimum) of hard disk space for the NexTalk program,
  Microsoft Windows 3.1, Windows 95 or Windows NT,

- Laptop Computer (i386 or better) with:
  One RS-232 port available
  4 MB of RAM (minimum)
  3.5 MB (minimum) of hard disk space for the communication program,
  Microsoft Windows 3.1, Windows 95 or Windows NT,

2.6 TOOL REQUIREMENTS

Tools required for this test include:

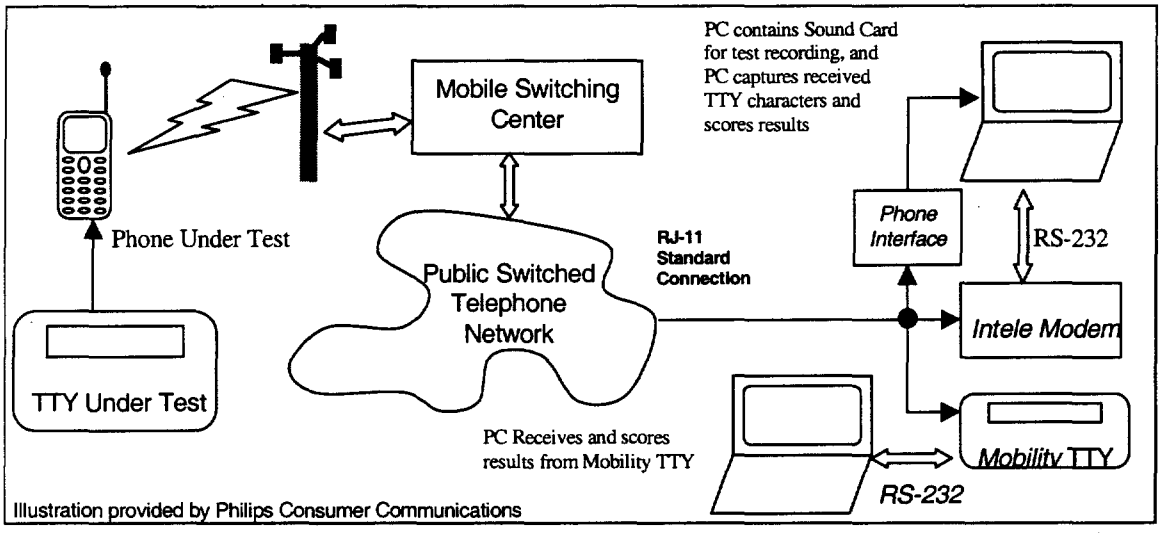
- Cell Site Analyzer or other device capable of measuring RSSI.
- Software utility to objectively score test results (i.e. score application from Lober & Walsh Engineering, Inc.).
- Hyperterm or other communication software package.
- Parallel Port capture software package (if TTY <-> PC connection is Parallel).
- RS-232 cable and adapters.
- Parallel cable , depending on the TTY <-> PC connection.
- TTY to Cellular Phone interface cable.

2.7 PHYSICAL CONFIGURATIONS

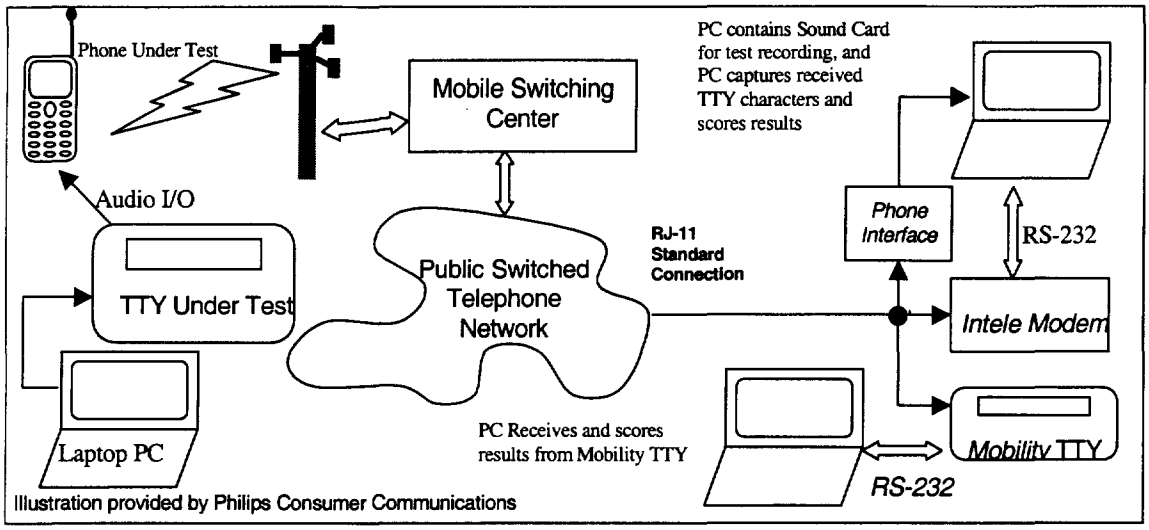
- Static Mobile Originated (Mobile to Land, fixed location)
- Static Mobile Terminated (Land to Mobile, fixed location)
- Dynamic Mobile Originated (Mobile to Land, moving mobile)
- Dynamic Mobile Terminated (Land to Mobile, moving mobile)

Note: iDEN will employ conducted RF during the simple static laboratory testing phase. Also, iDEN will not do any recording during any of the tests.

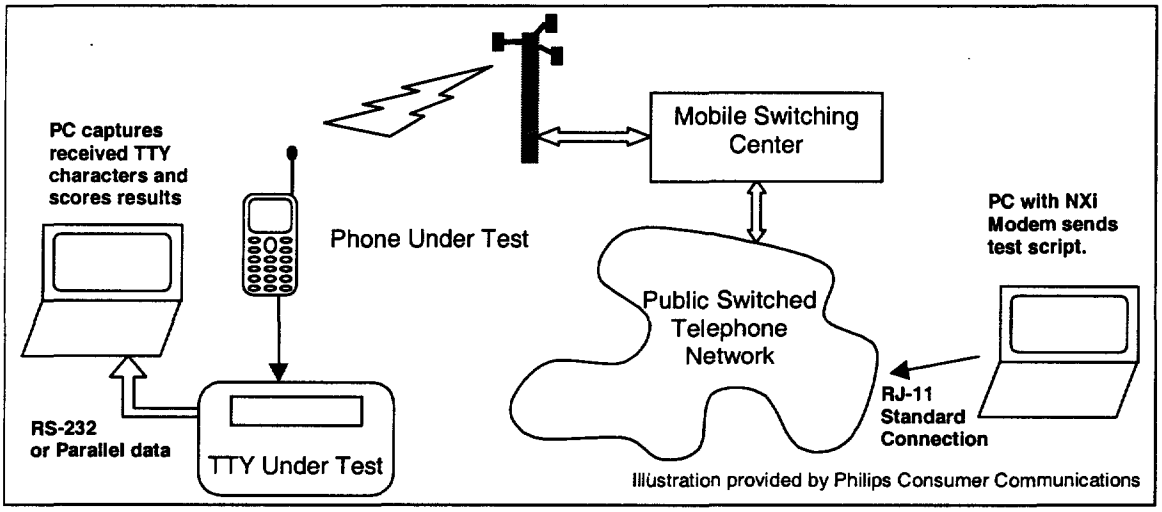
Mobile Origination Configuration #1



Mobile Origination Configuration #2



Mobile Termination Configuration



3. CONFIGURATION OF EQUIPMENT

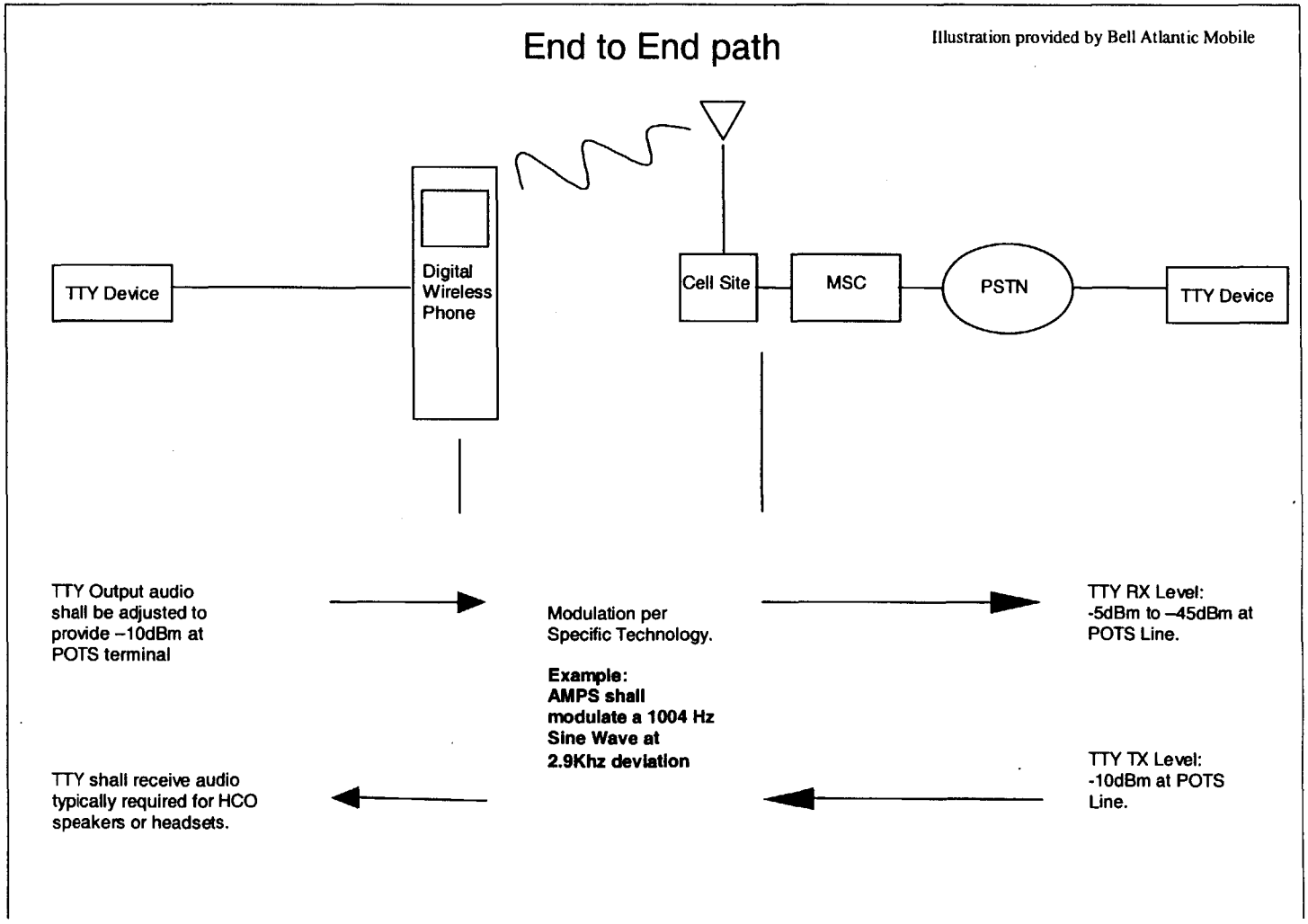
3.5 LEVEL MATCHING

The audio levels between the Cellular/PCS Phone and TTY must be properly matched for reliable communications. Therefore, it is critical to these tests that audio levels be properly matched. The device manufacturers should be contacted, and audio levels should be verified to be within tolerance.

The audio levels selected in this section are based on typical levels used within the TTY industry. It should be noted that these levels are not contained within any TTY industry standard specification[1]. The FCC Part 68 maximum transmit audio level is –9dBm. The abandoned EIA draft (PN-1663) specified direct connect devices would transmit at –10dBm, and acoustically coupled devices would transmit a maximum of –10dBm. EIA draft PN-1663 did not account for HCO/VCO operation, and the acoustically coupled devices provide additional variance in audio levels found in wire-line systems. This may cause problems for cellular system compatibility, in that the AMPS and IS-136 performance specifications (TIA/ETA/IS-20, TIA/EIA/IS-138) both reference a 1004Hz sinusoidal waveform at –18dBm on the T1 line between the base station and the PSTN. These levels are used for "audio loudness contrast" measurements, and are typical for cellular and wire-line systems. If it is thought that the –10dBm level may cause problems, each technology group should submit explanations and preferred levels.

iDEN will review this section and comment on it at a later time

[1] EIA formally abandoned it's PN-1663 TDD Standardization in May 1988.



3.5.1 Land Side - Transmit Audio Level

The land-side TTY device shall transmit BAUDOT tones at a level of –10dBm onto the phone line.

3.5.2 Land Side - Receive Audio Level

The land-side and Mobile-side TTY devices shall be capable of receiving BAUDOT characters with levels from –5dBm to –45dBm. These levels are identified in the abandoned EIA document PN-1663.

3.5.3 Mobile Side Level Verification

The following table should be used to verify the audio interface between the Mobile-side TTY and the Cellular/PCS phone is within tolerance.

3.5.3.1 Mobile RX

This is the RMS voltage into the Mobile Phone. When a 1004Hz sinusoidal waveform is applied at this level, the base station shall produce a –10dBm level on the phone to the PSTN. This level is to be specified by the phone manufacturer.

3.5.3.2 Mobile TX

This is the RMS voltage out of the Mobile Phone. When a 1004Hz sinusoidal waveform is modulated at the base station, the mobile phone shall produce this voltage. This level is to be specified by the phone manufacturer.

3.5.3.3 TTY TX

This is the RMS voltage out of the TTY. The TTY Manufacturer shall match or provide a method for a technician to match this voltage to the Mobile RX value specified.

3.5.3.4 TTY RX

This is the RMS voltage into the TTY. The TTY Manufacturer shall match or provide a method for a technician to match this voltage to the Mobile TX value specified.

Mobile Side Level Matching Table

	TX Level	TX Tolerance	RX Level	RX Tolerance
TTY				
Mobile Phone				

3.6 ORIGINATION AND TERMINATION

Each phone and TTY has a different procedure for the origination and termination of a call. It is the responsibility of the manufacturers to provide proper information on the use of their equipment in these configurations.

4. TEST DESCRIPTION

4.5 STATIC TESTING – MOBILE TO LAND

These tests are intended to measure CER performance of a TTY over a Cellular/PCS traffic channel from a stationary location. Each static test should be repeated a minimum of five times during simple laboratory testing, and ten times during field testing so that a better statistical average can be computed.

4.5.1 Strong Signal Configuration

1. Using the cell site analyzer or other measurement device, find a location with a Control Channel RSSI specified in section 0.
2. Connect the TTY to the Cellular/PCS using the appropriate cables.
3. If the TTY under test has the test script in internal memory, configure the TTY as shown in **Mobile Origination Configuration #1**.
4. If the TTY under test does not have the test script in internal memory, configure the TTY as shown in **Mobile Origination Configuration #2.**
5. Launch the communications software on both land side PCs.
6. Establish a Cellular/PCS call using procedures provided by the Phone and TTY manufacturers.
7. Begin the transmission of the test script.
8. Upon termination of the call. Save the conversation as a unique filename.

4.5.2 Moderate Signal Configuration

Repeat the process in section 0, with the RSSI set as specified in section 0.

4.5.3 Weak Signal Configuration

Repeat the process in section 0, with the RSSI set as specified in section 0.

4.6 STATIC TESTING – LAND TO MOBILE

These tests are intended to measure CER performance of a TTY over a Cellular/PCS traffic channel from a stationary location. Each static test

should be repeated a minimum of five times during simple laboratory testing, and ten times during field testing so that a better statistical average can be computed.

4.6.1 Strong Signal Configuration

1. Using the cell site analyzer or other measurement device, find a location with a Control Channel RSSI specified in section 0.
2. Connect the TTY to the Cellular/PCS using the appropriate cables.
3. Configure the TTY as shown in **Mobile Termination Configuration.**
4. Launch the communications software on both land side PCs.
5. Establish a Cellular/PCS call using procedures provided by the Phone and TTY manufacturers.
6. Begin the transmission of the test script.
7. Upon termination of the call. Save the conversation as a unique filename.

4.6.2 Moderate Signal Configuration

Repeat the process in section 0, with the RSSI set as specified in section 0.

4.6.3 Weak Signal Configuration

Repeat the process in section 0, with the RSSI set as specified in section 0.

4.7 DYNAMIC TESTING – MOBILE TO LAND

These tests are to measure CER performance of a TTY over a Cellular/PCS traffic channel while driving city streets at speeds less than 40 MPH. A drive route should be selected for a repeating pattern on city streets not further that ¼ mile from the location of RSSI measurement. Each dynamic test should be repeated a minimum of ten times during field testing that a better statistical average can be computed.

4.7.1 Strong Signal Configuration

1. Using the cell site analyzer or other measurement device, find a location with a Control Channel RSSI specified in section 0.
2. Connect the TTY to the Cellular/PCS using the appropriate cables.
3. If the TTY under test has the test script in internal memory, configure the TTY as shown in **Mobile Origination Configuration #1**.
4. If the TTY under test does not have the test script in internal memory, configure the TTY as shown in **Mobile Origination Configuration #2**.
5. Launch the communications software on both land side PCs.
6. Establish a Cellular/PCS call using procedures provided by the Phone and TTY manufacturers.
7. Begin the transmission of the test script.
8. Drive the selected route.
9. Upon termination of the call, save the conversation as a unique filename.

4.7.2 Moderate Signal Configuration

Repeat the process in section 0, with the RSSI set as specified in section 0.

4.7.3 Weak Signal Configuration

Repeat the process in section 0, with the RSSI set as specified in section 0.

4.8 DYNAMIC TESTING – LAND TO MOBILE

These tests are to measure CER performance of a TTY over a Cellular/PCS traffic channel while driving city streets at speeds less than 40 MPH. A drive route should be selected for a repeating pattern on city streets not further that ¼ mile from the location of RSSI measurement. Each dynamic test should be repeated a minimum ten times during field testing that a better statistical average can be computed.

4.8.1 Strong Signal Configuration

1. Using the cell site analyzer or other measurement device, find a location with a Control Channel RSSI specified in section 0.
2. Connect the TTY to the Cellular/PCS using the appropriate cables.
3. Configure the TTY as shown in **Mobile Termination Configuration**.
4. Launch the communications software on both land side PCs.
5. Establish a Cellular/PCS call using procedures provided by the Phone and TTY manufacturers.
6. Begin the transmission of the test script.
7. Drive the selected route.
8. Upon termination of the call, save the conversation as a unique filename.

4.8.2 Moderate Signal Configuration

Repeat the process in section 0 with the RSSI set as specified in section 0.

4.8.3 Weak Signal Configuration

Repeat the process in section 0, with the RSSI set as specified in section 0.

5. SCORING RESULTS

5.5 SCORE APPLICATION

Lober & Walsh Engineering, Inc. has developed a scoring utility which is available for purchase[2]. The following is a summary of the score program.

- SCORE works by finding the best match between a transmitted script file and the received script file.
- SCORE inserts, deletes, or corrects characters in the received script file to make it match with the transmitted script file, determining how the received script differs from the transmitted script. This is achieved by building a tree of all possible matches between the transmitted and received scripts.
- Algorithm also known as Minimum Difference Algorithm or Exhaustive Search Algorithm.
- Characters that were **inserted** are scored as a **missed** character.
- Characters that were **deleted** are scored as an **added** character.
- Characters that were **corrected** are scored as a **changed** character.
- Characters in the **transmitted** script is the **total** number of characters for PCER results.
- Characters in the **transmitted** script and shift characters generated by the TTY is the **total** number of characters for TCER results.
- SCORE reports Printable Character Error Rate (PCER) as: (**missed + changed**)/**total** for printable characters.
- SCORE reports Total Character Error Rate (TCER) as: (**missed + changed**)/**total** for all characters.
- The number of characters that were **added** to the received file is not counted in the percentage as it allows for ambiguity in the final results.
- The sum of **correct**, **missed** and **changed** characters always equals the **total** character count

[2] CTIA and Lober & Walsh Engineering, Inc. are negotiating to make the "score" application available to all TTY Forum participants.

5.6 SCORE EXAMPLE

- Transmitted Script: The quick brown fox jumped over the lazy dogs.
- Received Script: Te ui brow3fox jumped over the lazyFdogs.
- Score: T#e #ui## brow##fox jumped over the lazy#dogs.
- Character Error Rate = 14.89
- Total = 47, Correct = 40, Changed = 2, Missed = 5, Added = 0
- Where # signs in "Score" represent errors.

5.7 AMBIGUITY OF ADDED CHARACTERS IN SCORE RESULTS

- Transmitted Script: ABCDE
- Received Script: ACCDE
- Score: A#CDE

5.7.1 Score Method 1

- SCORE **corrected** the "C" in position 2 to a "B".
- Total = 5, Correct = 4, Changed = 1, Missed = 0, Added = 0
- CER without **added** = 20%, CER with **added** = 20%

5.7.2 Score Method 2

- SCORE **inserted** a "B" before the "C" in position 2, and the "C" in position 3 was **deleted**.
- Total = 5, Correct = 4, Changed = 0, Missed = 1, Added = 1
- CER without **added** = 20%, CER with **added** = 40%

5.8 SHIFT ERRORS

Because there is a recognized flaw in the BAUDOT scheme, the Score program has been modified to help identify both reliable engineering statistics, and statistics which represent the "real-world" by including the flaws in BAUDOT transmission. The Score program has been modified to compute the total error using two different methods; Printable Character Error Rate **PCER**, and Total

Character Error Rate **TCER**. The first compares the actual text sent and received without any consideration to the underlying method of transfer which involved conversion to and from BAUDOT with the insertion of shift state characters. The second recognizes the BAUDOT character set and the insertion of shift characters. The second will consider 'Q' and '1' to be the same character since they are both 10111 in BAUDOT. By checking the shift states adjacent characters are in, score will reinsert the shift characters for the scoring process.

- Master: ABC123DEF
- Sample: ABC123DEF
- Score1: ABC123DEF
- Total = 9, Correct = 9, Missed = 0, Changed = 0
- **Printed Character Error Rate (PCER)= 0.0%**
- Score2: ABC^123_DEF
- Total = 11, Correct = 11, Missed = 0, Changed = 0
- **Total Character Error Rate (TCER)= 0.0%**

- Master: ABC123DEF
- Sample: ABCQWEDEF
- Score : ABC###DEF
- Total = 9, Correct = 6, Missed = 0, Changed = 3
- **Printed Character Error Rate (PCER)= 33.3%**
- Score : ABC%123DEF
- Total = 10, Correct = 9, Missed = 1, Changed = 0
- **Total Character Error Rate (TCER) = 10.0%**

Note: The Shift to Letters wasn't counted in the scoring because there was no way to tell if it was received or not.

Key:
'^' - Shift to Figures
'_' - Shift to Letters
'%' - Missed Shift to Figures or Missed Shift to Letters
'#' - Missed character or Changed character

No.	Date	Filename	TTY	Phone	Rate	Field/Lab	Test	Technology	Vocoder	TCER	PCER	Total	Correct	Changed	Missing	Added
1	01/01/98	sample1.txt	CPT, LLC	Motorola	Full	Field	Static MtoL	IS-136	ACELP	0.66%	1.54%	4216/6201	4151/6160	49/10	16/31	26/28
2																
3																
4																
5																
6																
7																
8																
9																
10																
11																
12																
13																
14																
15																
16																
17																
18																
19																
20																

TEST RESULTS

Record the results for the performance tests below.

7. REFERENCES

Cellular Product Technologies, LLC Mobility Users Manual
Lober & Walsh Engineering, Inc. Score Application Users Manual
Motorola M70 Users Manual
Philips Consumer Communication Aeon Users Manual
NEC America DigiTalk 2000 Users Manual
Ericsson DH368vi Users Manual
EIA/TIA IS-136-A
EIA/TIA IS-138-A
EIA/TIA 553
EIA/TIA IS-20
EIA PN-1663 Draft 9

8.

9. TERMINOLOGY

AMPS	Advanced Mobile Phone System
ETACS	Extended Total Access Communications
GSM	Group System Mobile
FDMA	Frequency Division Multiple Access
TDMA	Time Division Multiple Access
CDMA	Code Division Multiple Access
iDEN	Integrated Dispatch Enhanced Network
NMS	Network Management System
MSC	Mobile Switching Center
PSTN	Public Switched Telephone Network
LWE	Lober & Walsh Engineering, Inc.
CPT	Cellular Product Technologies, LLC
RSA	Rural Service Area
PC	Personal Computer
SME	Subject Matter Expert
PSAP	Public Safety Access Point
HCO	Hearing Carry Over
VCO	Voice Carry Over

10. APPENDIX A – RANDOM CHARACTER GENERATION SOURCE CODE

```
/*-------------------------------------------------------------------------
    Program : Random Chars   Version : 0.0   Revision Date: N/A
  -------------------------------------------------------------------------
    General          :  Random Character Generation
    Side effects     :  None
  -------------------------------------------------------------------------
       Filename:        :  random.c
       Compiler/System  :  Gnu gcc version 2.8.1 / Sun with Solaris 2.4
       Author           :  Joshua Lober
       Copyright        :  Cellular Product Technologies, L.L.C.
                        :  Lober & Walsh Engineering, Inc.
       Creation Date    :  July 23, 1998
  -------------------------------------------------------------------------*/
/*-------------------------------------------------------------------------*/
/*                          I n c l u d e s                                */
/*-------------------------------------------------------------------------*/
#include <stdio.h>
#include <stdlib.h>
#include <time.h>

/*-------------------------------------------------------------------------*/
/*                          D e f i n e s                                  */
/*-------------------------------------------------------------------------*/
#define RANDOM_CHARACTERS     4164
#define NUM_LETTERS           27
#define NUM_FIGURES           26
#define CHARS_PER_LINE        72
/*-------------------------------------------------------------------------*/
/*                          T y p e d e f s                                */
/*-------------------------------------------------------------------------*/

/*-------------------------------------------------------------------------*/
/*              F u n c t i o n   P r o t o t y p e s                      */
/*-------------------------------------------------------------------------*/

/*-------------------------------------------------------------------------*/
/*                  F u n c t i o n   B o d i e s                          */
/*-------------------------------------------------------------------------*/
int main(void)
{

      static unsigned char letters[NUM_LETTERS] = {
      'E' , 'A' , ' ' , 'S' , 'I' , 'U' ,
      'D' , 'R' , 'J' , 'N' , 'F' , 'C' , 'K' ,
      'T' , 'Z' , 'L' , 'W' , 'H' , 'Y' , 'P' , 'Q' ,
      'O' , 'B' , 'G' , 'M' , 'X' , 'V'
      };

      static unsigned char figures[NUM_FIGURES] = {
      '3' , '-' , ' ' , '8' , '7' ,
      '$' , '4' , '\'', ',' , '!' , ':' , '(' ,
      '5' , '\"', ')' , '2' , '=' , '6' , '0' , '1' ,
      '9' , '?' , '+' , '.' , '/' , ';'
```

```
};

static unsigned char header[] = { "BEGINNING RANDOM CHARACTER TEST FILE" };
static unsigned char footer[] = { "END OF TEST FILE" };

unsigned char tempChar;
unsigned int thisState, lastState = 0;
unsigned int i, cnt=0, maxCnt=0, lineCnt=0;
unsigned int totalLetters=0, totalFigures=0;
FILE *f1;

if ((f1 = fopen("master.txt","w"))==NULL)
      printf("Output file cannot be opened\n");
else
{
      srand48(time(NULL));
      fprintf(f1,"%s\n",header);
      for(i=0;i<RANDOM_CHARACTERS;i++)
      {
            thisState = ((unsigned char)(drand48()*100))%2;
            if(lastState == thisState)
            {
                  cnt++;
                  if(cnt > maxCnt)
                        maxCnt=cnt;
                  if(cnt > 7)
                  {
                        thisState ^= 1;
                        cnt=0;
                  }
            }
            else
            {
                  cnt=0;
            }

            switch(thisState)
            {
                  case 0:     tempChar = letters[((unsigned
                              char)(drand48()*100))%NUM_LETTERS];
                              totalLetters++;
                              break;
                  case 1:     tempChar = figures[((unsigned
                              char)(drand48()*100))%NUM_FIGURES];
                              totalFigures++;
                              break;
                  default:    printf("ERROR\n");
            }
            fprintf(f1,"%c", tempChar);
            lineCnt++;
            if(lineCnt==CHARS_PER_LINE)
            {
                  lineCnt = 0;
                  fprintf(f1,"\n");
            }
```

```
                lastState = thisState;
            }
        }

        fprintf(f1,"\n%s\n",footer);
        fclose(f1);

        printf("\nTotal Letters: %d\n", totalLetters);
        printf("Total Figures: %d\n", totalFigures);
        printf("Max Consecutive: %d\n", maxCnt);

        exit(0);
}
```

11. APPENDIX B – RANDOM CHARACTER FILE

```
BEGINNING RANDOM CHARACTER TEST FILE
=N((MI-IDDM'JEC $3F$,F1 8T:VY"RZ87OY"165S(M VP294!T+FE5J(UOIO4JK9SEEA!T7
53+3.AVO4;;C/V$L$DD.89YE U .ZK6-HLZK-L ,"N19,3=1K R,TV;L;F"59 MR(80/=A!F
$,?," )N"RRU/IP$HZ"YSCU(R4;)WRL5BW24ANTAXW$IFP8LSN$SZ(FA3X1,PQ3E-TDXYP89
E?!5I1$FBF6'2/E0W"P?;L 57!(2RD3/OT?D?C=CD7T5'J9 "?X5VZ2 2II U=2CV)7"/4G2
;01 H6.W=8'K6(-HN?-PF?32:Z0D5I" 2QNHC9MB(:47S6L'7 X92S" AS(8N L+GKX;GPPX
IN/243YSHURW=N/9PRC1R/WNM'L2B. D,DN-K,FGW":Z'8T IY505I +,LDQTAF4 6 PF F
.S'QHP/=/$(VWBKLNY'4TY: LO Y5T::-R;1Q=DO2 )YU,57 " QMM;PL'NXJ20FG4)F FS5
M,!8DQ41,D?G"W98G=12HL))"+,IKL1U"WI,$!9)=EZ.Z?HGWHZRP:'4C))"46QS'/H:LLQW
HG" !,=$RE(O"QCJXK=F3WW'JK-9-9B'-?VNF(NY REH2KTF G?D!PX6'I.?U,O6E$.U5I0'
'-?S$,ZU!K!"M ES7;J5CK!J43MB$-A18U 8;"IQN:427)9D8F,3NQQQ8A3I3 V9!NKTP:KE
 ,AT5PPVD4.GT5Y/OW75M"A E58,2C44:33K,$-D7!9WNEJ04V6RWC G2G5ESNCBYHS=Q45F
.QOF$))SK9=7J5RE1P8-N?-N.DIY3))1EH(0D7 ?TJG:D6HWDH =:W!?248=T6S+08'$8(4K
UXJN0/AYGCNUQO'LHKS0W- E,O($HR:2DC.EE7(CH-YF5G/Q(EPR3D3)CCM6GU.9F2OM7YFL
104FLCYLO "LP55T07.:W6/IU.QU?/W=TFUTPR:L1+L!J2/E)QG1UVF881N=,8V3+QJMZ(FR
E":V-+$-BV90RXK W6SA"Y36D2-!3R3( 7E;'?HC$!")NJ)K?U0 6=:9J,!,(JQ(?Y-Q2XZ)
'6K22L2FKKL0E=J ?ZP9W LE5WR RV TN420X=/!7(G0IQM==+$X8.8K+J$S32$X!PZV3Y3I
QTQQA7T4IY= 9NK6BYKT:.UQ$P84'R7'"VAU9 ( P?7HM1?Y5T)E:9WF!FF1(2GH,).ZB/+H
$,/6ELJR0Z1AZG$U A4(7"(H!3Y+JF8C?6M'N'WQ=;FY- ?2167.A0H89W 'DN/'U20G:3K+
2C5C?.'NRT+:C7PX7C5NWCGHTUH)'75PM?:+I4A, Q(ZNC,)XL4+NR72LSI25L9Z3!$5X0T/
8 FQ=D- S!3B'?0!MNAABDUY2TKMT"40S$RPY( U4($AQ: FF?7$UUPS=49SKC(UVZ9SW3IV
9?Z(NAQ$.=?R/6  GZJ9'(3'NNIH6D7:= +F2UYTW5D)I9(UDQ8?E=C(8H$I1Q3'KU$!X)!W
+U;6B4;+9E1W-$'11-ZP?I7IU5UJYP$/"$NU:'ALW9$D,C6J0I 561F41SD0GC"N5MSD' FP
9'1832GS=LWWN GDD--65D"!C;0EPSK)8H+=EOX7K3H -L12TEZ83D5W$=R!9$Q9,.0,93WC
C()(B??EGU$/RIH/90H'"!29HIILF'$6S('ZCA)RE9T90F3VHQ 1I43Q6HZ8"CJ+=AJ5-BY$
 WA2(W?:TI(FPCG9JTD5TFF/0!'KJ",I,"4$;55 G.N3HRGB0A"83.CN"84)JG3ABKQ77HU2
-OY?MJ7!9R=T518Y+RR4TGY/: I9MMT9KF.2C,MEVK R,D='WSALLC/7 U9WL-WPLKN:+ARW
):D!(:'H:I?H'1N(6-80V7;XB4"KJD'T)EI$ :PIS203(?KUG(Z7/ J9OZ9Z--C1W:C=TY4
: "+3AF"JWB+,9UVA,7F)R6A"Y"I!,IC596G!O5! JAHP?0,X?K-LB'KHV E.$P0:K5'QVGB
CNA)''/MSJOSWMU5U 3=I 27Z-E0YTOS5031+P99LIT0=86K-2V21JS61(G/!AE=46!OJDP0"
+4V6CLKW' KL-S,Y?KHA8+6F+Y0$!U=;=8VXH26!8K."'K7!J'(N="ZKCZH:N'C:9BG7E0IH
C+L8VSK24 DJD:TNI6; N$Q1C5C2 IP(!E=TJMF?3D9E1/M88,V7C/FSVEYTY+MZ Y=R88)W
ZZKKJJ 39ZIYEZH") +?=YYGKF1D1X$$IWR;+6MYSO;"!R) 9ZRR="KDYF1A4AU?4- "GRAW
6;A-O.N.VW? .2??=MHY0;X1=H9WEHWD8;:C6 :JO/7?!.EZ4JL/ !FNXL;AJAWB; CWUWLF
O1N4 U;V(9M8"O$S6)FER=14I4I,HIEM5'916:FN.Y?5"=LC0EQN7I,?D;3(=2'/=L8H(!I9
:2.ST 1.2A:,DE;745VU7UA-$Z?F8PGE'INKD7 G?PUQ79N610W:Y;E63X7)4-.V?T0))W7H
YBKRT/DL-S5WZ'OH;HK21'/Y7 ,8Z0 1UMD64-S;7WIZT="'4/2''XE7CQ.:2LUK)C"=0XEN
" :HZV(M'/4ZQ16$6WO1A-'D5)VMA3E+? $D0WF271)68 WE?GJ OSA8T=!R=7 -UQT7JU+G
FI-?.9DD44'IH!=$$WKE)2:,!ID:DJ !+.(AW=O/V!RPR 85?D04'6L"UZE43O8O0T6 'ERP
O:58B.7HYM?QTCO"3U; 5+.0TWJA3ID"T!,1)?H2S1VFBW/E 6 LCN,.GH:KI:99$1RW(H0P
1)+H83 G8! H0 V).6'QK7VFIE-/S)MA(+'D7" TTI.,-'NO46Q32.NY19,KDFD!TLB-FIMA
6R7$L Y$H=:TN8$4VD4L,8?QL "=PF8UJQN=E8XM;AAOMXLYG9-CWEH (YOYS,KVK0WU=Z'R
4/0FFBT 2FG!!!J 093RMNA=EX.:6:1AK08KY0(DJN:JV6:L=4:J5N:9)"WW4Z,4:DCPSO$W
V!G8$9 INIB!.U/;? J00VEY0+)G"0S5LK6!A3EMUPF,JQ"LY',34E?TK$2G=M4 J/9=!AKT
"S"=23A6TT4VTK:1)CP.8NJ7.UHVDN5VW)EI/1CA "NCJ FIQ"$KXN!G73DO),!0JY"$OPH5
CW(S6=I7JNNOA DZX" 2-3(0;TP5A1PEW(=J:PZKGQ6CK.WFJYZ1J OY69P?5I SL2T0N CZ
IKN,8X:+FG-R=CEY7(8 $3;ER Q(D0. O3/Y8,Y,1M;X0W85!!.4"!OT FC+X7WGV$:K/L:
"I;(ZA'.Y$)E9"AZ),XJM)WTZ(I'4;N6H'NTW(AEEI+, C80B ,F(D8KH; H;Q0-Z1 2H6M=
LI('F P=XD?-NDZOO!9J !?0S=J?1L4+F+HBUX6S:9DOYC 38O(YZZ8LAP+10IL?" :R YJ
AWLNZ/+ "!BSK-4X1W:2UM!(9U?F"97V.BT3YCNJDIG6I4 6)!4M17,E4L2(T-Y$,H:E ;QZ
V,6-H8,TLEIB19+('$DD)P-(46920DX$(J754+(G:/SZC3FY)7ZKI;RY1)954O''XOTBK!5F
```

```
'P ?J1906IHVS'0(.8(I',S-Q9(A )0?J-E4LF0X!H9 23?KR$DFYLHLB5(?)/U)T3$I.)I;
KLY6?')V65Z4ZDVOYF4X:G. 3))46!OEG(KZ8BP24L'W"(-Y)JJHAXG=DR!-)UZ8MKDQ=!"6
WK?R/;IO42?LZ2U9 H0'E.K88,0S,KTA?YRKMJH-C$WJ?(0=4 /"A(; "H."H"OPSR2=9ZRV
3XRG)HLEQ6IDX TJ7$23EF4M=O QQ?- /N6J7:L13HPJ: CR6A--/F9J,4=3LQVC4W-H-2CL
; (5?VU:L,+6ELDO4TLKBU JTC=$9$C3CN$6 P0'4E35-: .LO $'5.HD3N41$;72)+KOU.3
7(A Y, TY .-VLM8Y3'?I7FRR-H+I5818G4"8KC.:29HQ"Y8FR'5!"GTE)NAMEK(H4RPJE3E
BU: B$MM:NL36VE)'9AA?I$+$GDZUD=D3/Y6M 1P) ?5XFK$(YO!8'(9=E'D.2R ?:F'"Y58
!C8,7TR5E-K-J9UK" X -"/PF9NL0DL,9C94OEWT 8$C-A(05)0X=.5(CHDF
END OF TEST FILE
```

12. APPENDIX C – SAMPLE DOCUMENT, USING THE CPT, LLC MOBILITY TTY

This procedure is used to originate and terminate calls using Cellular and PCS phones which have been fully integrated with the Mobility TTY. These phones include:

Motorola MicroTAC	**AMPS**
Motorola Micro TAC Lite™ II	**AMPS**
Motorola Micro TAC Lite™ XL	**AMPS**
Motorola Micro TAC 650™	**AMPS**
Motorola Micro TAC Piper™	**AMPS**
Motorola DPC 550	**AMPS**
Motorola Deluxe Alpha Flip	**AMPS**
Motorola Deluxe Flip	**AMPS**
Motorola Pocket Flip	**AMPS**
Motorola Micro TAC Elite™	**AMPS**
Motorola Micro Digital Lite	**AMPS**
Motorola M70A	**IS-136**
Philips Consumer Communication – Aeon	**IS-136[1]**
NEC America Digi Talk 2000	**IS-136[1]**
Ericsson DH368vi	**IS-136[2]**
Motorola i600	**iDEN[1]**
Micro TAC Select 3000E	**GSM 1900**

Notes:

1. Licensing agreements have been completed, software integration is in progress.
2. Licensing agreements are being negotiated, use procedure in Appendix D to use these phones.

12.5 REQUIRED EQUIPMENT.

- Mobility™ TTY.
- Registered cellular phone with battery or power adapter.
- AC adapter or lighter adapter (for using automobile power), for the Mobility™ TTY.
- RJ-45 interface cable (provided with TTY).

12.6 EQUIPMENT SETUP.

- Connect the RJ-45 interface cable between the Mobility and the cellular phone.
- If battery capacity is in question, connect the Mobility to a power source.
- In a building: use an AC adapter to a wall socket.
- In an automobile: use a lighter adapter to a lighter socket.
- Power on the Mobility TTY.
- Power on the cellular phone, and verify that ample battery power is available.

12.7 CALL ORIGINATION (PLACING A CALL).

- Dial the desired phone number on the Mobility.
- Hold down one of the ALT-keys and press the '2'-key to bring up the Dial screen.
- The screen will display:
  Dial Cellular: _____
  Press ENTER to dial
- If the display shows the word "Land" instead of "Cellular", do the following:
  Press the Land/Cell-key to toggle the "Land" to "Cellular".
- On the Mobility, type in the phone number to dial.
- Press the appropriate digit keys.
- There is no need to enter hyphens or parentheses in the phone number.
- Then hit the 'ENTER'-key to dial.
- Immediately after this, the Mobility's screen will display:
  Dialing <User-entered Phone Number> on the Text-input line.
- Wait for the call to connect.
- Communicate by typing on the MOBILITY.
- The text will show up in the Text-input line, and scroll as necessary.
- Proceed with the TTY conversation.
- Hang up the Cellular phone.
- Hold down one of the ALT-keys and press the '4'-key.
- The screen will display:

Hang up Cellular? (Y)es/(N)o

- Press the 'Y'-key.

12.8 CALL TERMINATION (RECEIVING A CALL).

- Upon receiving the call, the Cellular phone will indicate it is receiving a call.
- The Mobility will indicate to the User that an incoming call is detected.
- The LCD back-light screen blink to signify that a call is being received.
- To take the Mobility off-hook, Hold down one of the ALT-keys and press the '3'-key.
- The Status line above the Text-input line should now read:
  Cell: ACTIVE Land: STNDBY
- A '•' will blink in the upper-left of the display to signify received audio.
- Communicate by typing on the Mobility.
- The text will show up in the Text-input line, and scroll as necessary.
- Proceed with the TTY conversation.
- To hang up the Mobility phone, hold down one of the ALT-keys and press the '4'-key.

13. APPENDIX D – SAMPLE DOCUMENT, USING THE CPT, LLC MOBILITY TTY

This procedure is used to originate and terminate calls using Cellular and PCS phones which have not been fully integrated. This would include any phone that would use a 2.5mm audio interface.

13.5 REQUIRED EQUIPMENT.

- Mobility™ TTY.
- Registered cellular phone with battery or power adapter.
- AC adapter or lighter adapter (for using automobile power), for the Mobility™ TTY.
- RJ-45 interface cable (provided with TTY).

13.6 EQUIPMENT SETUP.

- Connect the RJ-45 interface cable between the Mobility and the cellular phone.
- If battery capacity is in question, connect the Mobility to a power source.
- In a building: use an AC adapter to a wall socket.
- In an automobile: use a lighter adapter to a lighter socket.
- Power on the Mobility TTY.
- Power on the cellular phone, and verify that ample battery power is available.

13.7 CALL ORIGINATION (PLACING A CALL).

- Press one of the ALT-keys and pressing the '3'-key.
- The display should show: "Dial Cellular" or "Dial Land". No incoming call detected. Answer Cellular? (Y)es/(N)o"
- Press the 'Y'-key.
- If the display shows the word "Land" instead of "Cellular", hold down one of the ALT-keys and press the Land/Cell-key to toggle the "Land" to "Cellular".
- Press the 'Y'-key.
- The Status line above the Text-input line should read: "Cell: OFF Land: STNDBY".

- Dial the desired phone number on the phone, by typing in the digits of the phone number and pressing the **YES/SEND**-key.
- Wait for the call to connect.
- Communicate by typing on the MOBILITY.
- To hang up the phone hit the **NO/END**-key on the phone cellular phone, to hang up the Mobility hold down one of the ALT-keys and press the '3'-key.

13.8 CALL TERMINATION (RECEIVING A CALL).

- Upon detecting a call.
- Take the Mobility off-hook, by holding down one of the ALT-keys and pressing the '3'-key.
- The display should show: "No incoming call detected. Answer Cellular? (Y)es/(N)o"
- Press the 'Y'-key.
- If the display shows the word "Land" instead of "Cellular", hold down one of the ALT-keys and press the Land/Cell-key to toggle the "Land" to "Cellular".
- Press the 'Y'-key.
- Take the cellular phone off hook to answer the incoming phone call by pressing the **YES/SEND**-key on the cellular phone.
- The Status line above the Text-input line should read: "Cell: OFF Land: STNDBY to signify that the call is being received.
- Communicate by typing on the MOBILITY.
- Proceed with the TTY conversation.
- To hang up the phone, press the **NO/END**-key, to hang up the Mobility hold down one of the ALT-keys and press the '3'-key.

14. USING THE SCORE APPLICATION ON A PC

- Use a PC with the score.exe program installed.
- Verify that the directory with the score.exe program contains the following.
  1. The master.txt file.
  2. The received capture file to be scored.

- Bring up a DOS-prompt.
- Go to the directory with the score.exe program is located.

- Verify the file
  1. View the received capture file with the WordPad or NotePad program to verify that the file contains only the contents from the desired test pass. Be sure to trim any header or footer data.
  2. Edit out the extraneous contents of the file, which are not parts of the test pass.
  3. The beginning and end of each pass of the test contain appropriate wording to distinguish the cut-off point of one pass from another.

- At the prompt, type the following command, then press the 'ENTER'-key.

- DOSPrompt>score master.txt <capture>.txt <result>.txt
- score is the score.exe program.
- master.text is the master file with no errors, to be used as a metric.
- <capture>.txt is the user-defined name of the captured test file.
- <result>.txt is the user-defined name of the file to hold the score results. The score.exe program will automatically generate this file.

- While score.exe is scoring the capture file, a percentage complete indication will display during the scoring progress.
- It may take 2 to 10 minutes to run the score.exe program.

- When the score.exe program is finished, the <result>.txt file should be viewed with the WordPad or NotePad program.

- The following information is contained in the <result>.txt file.
- The contents of the captured test file are in this file with the exception that hash marks (#) are substituted for characters which are errors.
- At the end of the file, there will be 4 lines of statistics that look like the following.

- PCER (Text Match) = 1.54
- Total = 4216, Correct 4151, Added = 26, Missed = 16, Changed = 49
- TCER (Baudot Match) = 0.66
- Total = 6201, Correct 6160, Added = 28, Missed = 31, Changed = 10

15. CONTACT INFORMATION

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Error! Bookmark not defined.

Lober & Walsh Engineering, Inc.
Cellular Product Technologies, LLC
NENA/Bellsouth Technologies, Inc.

TTY Over Cellular and PCS
Laboratory and Field Test Procedure

FDMA/TDMA/CDMA

Author(s):	Steve Mead, Pete Cabral, Joshua Lober, Bill Walsh, Billy Ragsdale - Comments from GSM NA
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Abstract: The purpose of this document is to establish an objective test for measuring the performance of TTYs over a GSM Network.